Aggregation based Cuttlefish fishery

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Cephalopods are actively sought in artisanal fisheries with highly selective gears and fishing techniques based on knowledge of their biology and behaviour (Reid *et al*., 2005). Such techniques use substrates for egg deposition or use live sexually mature females as lures for attracting males while targeting spawning cuttlefishes.

Benthic FADs in the form of basket traps has been the most popular cuttlefish fishing method since olden times (Watanuki and Kawamura, 1999). Basket traps were employed around Inland Sea in Japan, Atlantic coast in Europe and by countries around the Mediterranean Sea for cuttlefish. Most benthic trapping and potting is carried out in reefy areas, where fish and other animals are concentrated by the sheltered nature of the bottom, either for protection or for feeding purpose. Japanese fishermen have been using cuttlefish trap for *Sepia esculenta* as early as 1660's. Full-scale trap fishery began in 1920's, when fishermen noticed that the introduction of spawning substrates inside the traps facilitated the capture of cuttlefish. Trap fishing practices, which was popular in western Japan later spread to much wider areas including Korean Peninsula.

Besides traps, bundled twigs as spawning nests for squids were also used in Japan. These traps were placed with stone sinkers for luring egg laying squids and were targeted by various types of gears including the boat seines. A simple but very efficient mid-water FAD made of rope, in combination with natural plant material/ artificial discarded material is used for attracting cuttlefishes along Gulf of Mannar (Samuel *et al*., 2005) and southwest Indian coast (Sasikumar *et al*., 2006; Thomas *et al*., 2010). Devices for anchoring these FADs are the simplest sand filled bags or stone-and-rope arrangement. Hand-jigs are operated with these traditional FADs in cuttlefish fishery. Along the southern Indian coast, artificial reefs are conventionally used by artisanal fishermen in rocky areas to attract and aggregate fishes closer to the shore (Kurien, 1996). Coconut leaves and screwpine leaves are dumped in the reefs mainly to attract cuttlefishes. Decaying leaves attract large number of cuttlefishes to the areas and provide ideal environment for the females to lay their eggs (Philipose, 1996). Cuttlefish and squids deposit voluminous egg-masses amidst these concrete modules. At present, the natural plant materials are increasingly replaced by plastic pet bottles and discarded synthetic fishnets in cuttlefish FADs.

As part of their life cycle cuttlefish exhibit onshore migrations to favoured breeding grounds for maturation and spawning. Coastal species of squids and cuttlefishes congregate in annual spawning congregations for facilitating one-to-one transfer of spermatophores. The availability of suitable substrate in the inshore areas and the suitability of the bottom substrate conditions for spawning the egg masses also play a significant role in migration, aggregation and spawning. Observations on spawning behaviour of cuttlefish indicates that the females are attracted to hard spawning substrate such as submerged rocks, sunken wood, aquatic plants, seaweeds, coelenterates etc. for attaching their eggs. This behaviour of cuttlefishes to migrate to inshore areas in search of spawning substrate for laying of eggs on submerged substratum makes them attractive targets for fishery, and they are effectively caught in FADs. FADs consisting of natural or artificial substrates with a bushy appearance are reported to serve as 'good' spawning substrate for the female cuttlefish (Samuel et al., 2005). Seabed consisting of either sand or muddy sand or shells mixed with sand around reef is reported to provide excellent fishing grounds for cuttlefishes.

The cuttlefish FADs has the advantage of being moored on these uneven sea beds, which are preferred spawning areas of cuttlefishes, where trawl nets cannot be used. The female cuttlefishes are first attracted to the FADs and are followed by the males. Immature cuttlefishes are rarely encountered near the FADs.

The biological attributes of the target species are exploited in the traditional and artisanal fishing methods for cephalopods. This tendency of mature females finding a sheltered place for spawning near FADs results in cuttlefish aggregation, which in turn increases their vulnerability to the moving jig. The universal habit of the cephalopod to attach also lures them towards moving jigs, leading to entanglement with the hooks. The elaborate courtship and the frenzied breeding activity, with males seizing at almost any moving objects in an effort to achieve mating, leads to their easy capture by jigs in the spawning ground (Boyle and Rodhouse, 2006).

Cuttlefish aggregation method in Karnataka

In Karnataka, cephalopods comprising of squids, cuttlefishes and octopus are predominantly exploited by trawlers and to a lesser extent by other gears. In 2004, fishing operations for cuttlefishes using fish aggregating devices (FADs) became prevalent in Karnataka waters by fishermen from southern coastal Districts of Kerala (Sasikumar *et. al.,* 2006). FADs are placed in uneven rocky areas where gillnets and trawlnets are difficult to operate. Good catches of cuttlefishes are taken since these FADs are attractive to the targeted resource during the spawning time. The artisanal hook and line fishermen of the south, migrates seasonally to north for fishing when the weather in their traditional home grounds becomes unfavorable due to northeast monsoon. Initially, when FADs were introduced for cuttlefishes, the migratory fishermen teamed up with the local artisanal fishermen for crafts. The later years were characterised by enormous presence of fibre boats operating in the southern coast to shift northwards, temporarily during the cuttlefish fishing season. Apart from coconut spadix, locally available casuarina plants that are ideal spawning materials having firm and slender leaves and bushy branches were also introduced for FAD construction. Of late, FADs were constructed using non-biodegradable materials such as discarded fish nets and plastic bottles.

The operational area for the fishery extends off Manjeshwara in south (north Kerala) to Karwar in north (Karnataka). Prior to the commencement of actual fishing operation, few trips are made to survey and select suitable areas for laying the FADs. Since rocky reefs and muddy areas in coastal waters are biologically more productive than barren sandy areas, rocky substratum with firm bottom is preferred for deploying the FADs. A preliminary survey of the sea bottom is carried out using ridged lead weight (1-1.5 kg with grooves) to fix the areas with rocky substratum for fishing. A rope is tied to the weight and it is dragged on the sea bottom. Survey is done perpendicularly to the shore from 10 m depth onwards. The lead-weight is periodically lifted for examining the type of sediment adhering to the grooves. The selected sites are marked using GPS and the prefabricated FADs are deployed in these areas at depths varying from 25 to 45 m.

A variety of materials are used as FADs to attract various species of marine organisms and for enhancing the fisheries. FADs introduced in Karnataka were fabricated using coconut spadix fastened with nylon ropes. These are eco-friendly, and on decay promote growth of periphyton and other food organisms. This in turn attracts large number of fishes including cephalopods, as they provide ideal feeding and breeding ground. Each module of the FAD consists of 50-60 numbers of coconut spadix tied at 0.2 m interval using 3 mm nylon rope into a 10 m long section. These modules are placed at the marked places on the sea bottom and the modules are anchored by fixing weight to both ends of the lines. Anchor used are generally cement gunny bags filled with sand. They are fixed to both the ends of the module so that it can neither drift away nor be shifted from the site of installation.

FADs are positioned on the sea bottom 4-5 days prior to the commencement of fishing. The materials are transported to the site in traditional crafts. On reaching the site, which is previously marked, the modules are dropped overboard at predetermined locations. Each unit sets about 100 numbers of such FADs at

500 m interval, on rocky sea bottom, in east-west direction along the coast, so as to provide shelter and maximum protection to the shelter-seeking organisms. The modules are installed on the seabed at depth ranging from 25 to 45 m; 25-40 km away from the seashore and their positions are marked using GPS.

The cephalopods, which get aggregated near the FADs, are caught using hand jigs. They are fabricated with barbless steel hooks. Four hooks (# 9) are wound around lead-weights of 5-6 inches of length in a row, using wire-rope. Each jig is attached to a monofilament line of 3 mm diameter. Each fisherman uses one line with a single jig at a time.

The craft used for the fishery resemble the regular outboard craft used for operating the drift-gillnet. However, these crafts have a flat raised deck. These fibre boats with flat bottom assist easy movement on board. They have an Over-All-Length of 7.5 m and are fitted with 9.6 HP outboard engines.

Crew consisting of five members sets out for fishing by 0400 to 0530 h. Each unit carries GPS for locating the submerged FADs. On reaching the ground the craft is anchored above the FADs, so that the vertical jig lines operate right above the FAD. The jigs are released manually to the bottom and as the jigs pass over the cuttlefish shoals, individual cuttlefish gets hooked. The line is hauled up manually and the cephalopods are unhooked on the raised platform of the craft. The lines are again released down to repeat the operation. Fishing continues as long as cuttlefish are available near the FAD. The fishermen use cotton gloves to protect their hands during the operation. The craft remain anchored throughout the jigging operation. Fishing is done at 30-35 FADs on a day so that each FAD is fished once in three days. Operation that commence at dawn continues till dusk (6.00 pm) and the crafts return to the shore. The crafts do not have storage facilities and the catch is kept covered without ice on the deck till it reaches the shore. Catch consisted only of the pharaoh cuttlefish, *Sepia pharaonis*. Cuttlefishes are sorted based on their size and sold.

The crew operating the jigs is migrants and generally belongs to Kerala and Tamil Nadu. Locals involved with this activity finance the fishing unit. They provide advance for the craft. These locals are also engaged in the marketing of the catch and get back their advance with profit in the ensuing fishing season. Cuttlefishes caught by jigs are taken by the processing plants.

The FADs set using natural materials like coconut fronds are biodegradable as they decay in a very short period time. Hence, they are eco-friendly, at the same time, because of their short-life, it warrants recurring costs for the fishermen. In spite of their small size, it is observed that they act as good habitat enhancement units and help in aggregating large numbers of spawning cuttlefish. Therefore, in spite of increased catch rates with high profits in certain months, such fishing practices, targeting ripe cuttlefishes should be done with prudence.

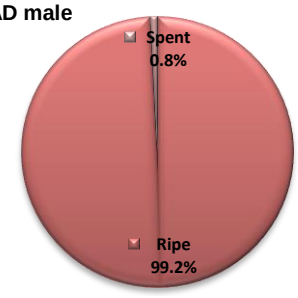
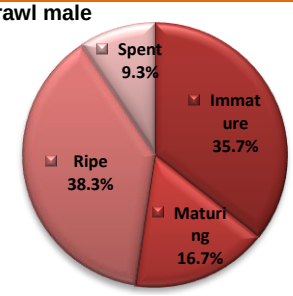
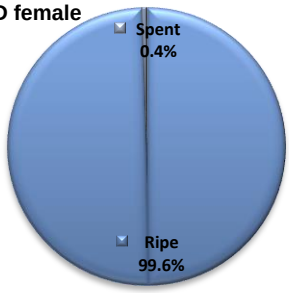
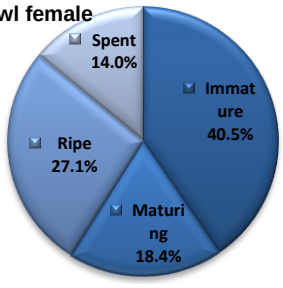
There are concerns that relate mainly to issues of resource sustainability. The use of FADs increases the vulnerability of the spawners to exploitation resulting in increased catch rates. This leads to rapid depletion of resources and hence such practices are discouraged in many countries. In this regard, there are also concerns on the number of FADs used as well as attempts to reduce the fishing effort on the FADs in some countries.

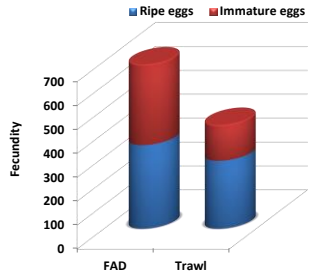
Apart from the biological threat caused by such fishing practices, social problems too have emerged in this area due to gear interaction and access to resource. The high profit rate for the fishermen engaged in this fishery, and the fact that such activity is carried out only by the migrant fisher-folk from Tamil Nadu and Kerala have resulted in discontent among the locals. Further, the FADs get entangled in the trawl nets of single- day boats which, also operate in the same area leading to conflict between trawl and jig-operators. This may even lead to the destruction of the eggs attached to the FADs. The FAD fishery was restricted in certain areas during October 2005 to April 2006 because of conflicts between local and migrant fishermen, but was later resumed from September 2006.

Comparison of FAD associated & unassociated cuttlefishes

The FAD associated hook and line fishery is a selective fishing technique for *S. pharaonis*, whereas, the trawl fishery is non-selective and the catches were composed of *S. pharaonis*, *Sepia elliptica, Sepia prashadi, Sepia trygonina* and *Sepiella inermis* (Sasikumar *et. al.,* 2009). The *S. pharaonis* catches from FADs that was less than 1,000 t (16%) until 2004-05, showed a steady increase from 2006-07 to over 6,000 t contributing to 48% of the total production from the region. Hand-jigging accounted for ca. 50% of the mean total production of *S. pharaonis* during 2006-2012 periods.

From 2008-09 onwards both the FAD associated fishery and the trawl fishery registered a declining trend in total production and CPUE. Clear differences existed in the abundance of cuttlefish near FADs, where, mean catch rates was initially ca.36 times more than the catch rates in trawl. Catch per unit effort near FADs registered a decreasing trend from 120 kg/h in 2005-06 to 59 kg/h in 2011-12. Catch rates in trawl varied between 1.2 kg/h in 2004-05 and 3.5 kg/h in 2008-09 and thereafter fell to ~1 kg/h. Prices of cuttlefishes have been on the rise for the past ten years, although there have been ups and downs. Average price of *S. pharaonis* increased from INR 50/kg in 2004 to INR 200/kg in 2012 yielding higher value per unit hours in recent years.

Parameters	FAD fishery	Free schools
Species composition	• Single species (*Sepia pharaonis*)	• Multiple species (*S. pharaonis* (dominant), *Sepia elliptica, Sepia prashadi, Sepia trygonina* and *Sepiella inermis*)
Size composition Dorsal Mantle length (DML)	• Adult cuttlefish • Size range:14-38cm DML • Mean size: 26.8±4.25cm	• Adult cuttlefish with recruits during Jan-Feb • Size range:3-40cm DML • Mean size:16.7±8.05cm
Reproductive status of assemblages	• Spawning • Spent	• Immature • Maturing • Spawning • Spent
Reproductive status of Male cuttlefish	FAD male 	Trawl male 
Reproductive status of Female cuttlefish	FAD female 	Trawl female 

Parameters	FAD fishery	Free schools
Gonadosomatic index (GSI)	High GSI throughout the fishing season Female GSI : 3.6-6.2 Male GSI : 1.2-1.5	High GSI only during spawning season Female GSI : 0.7-2.2 Male GSI : 0.5-1.0
Nidamental Gland Index (NGI)	High NGI throughout the fishing season Female NGI : 4.4-5.7	High NGI only during spawning season Female NGI : 0.8-2.7
Presence of ripe eggs	Ripe eggs present in females throughout the fishing season	Ripe eggs in females – present only during spawning season
Proportions of ripe to immature eggs		

Management options

The artisanal hook and line fishermen, known for their intricate practical knowledge of coastal fisheries and fishing skill have designed and fabricated these structures based on their understanding of cuttlefish behaviour. The method of FAD construction and deployment also includes designing of suitable structures for egg deposition, selection of spawning season as well as suitable sheltered area for their deployment based on the characteristics of the targeted species. It is evident from the biological aspects of cuttlefish assemblages caught near FADs that the hook and line fishery targets the pre-breeding/ breeding cuttlefishes. On an average nearly 1.2 million spawning females were exploited by the FAD associated fishery annually. Over the years the loss in recruitment due to FAD based fishery was estimated to be ranging from 6.3 to 12.3 million in the region. In addition, introduction of torn and worn out net material, plastic pet bottles and other artificial materials as a replacement to the biodegradable material of plant origin can lead to significant environmental consequences. The ecological consequences of the abandoned net material acting as ghost nets, trapping, entangling and killing fishes and shellfishes also requires serious considerations.

The spawning stocks of cuttlefishes exhibit a strong association with the egg laying substrates available in the spawning ground. This increases the vulnerability of the spawners to FAD based fishing gears. Given the higher commercial value of the cuttlefish, it is economically short-sighted to target spawning stock for a short-term benefit. Therefore in the management context, the fabrication and deployment of all materials for cuttlefish aggregation during spawning period need to be prohibited.

Though FADs can be an effective fisheries enhancement tool, there are few negative aspects in their deployment. In the current observation, the presence of only spawning individuals in FAD assemblages indicates that the cuttlefishes are attracted towards the submerged substratum for attaching the spawned eggs. In the process, the spawning individual aggregate and therefore increases their susceptibility to exploitation. Despite the fact that, fish aggregation may be highly adaptive, imparting several advantages to group members such as decreasing the risk of predation, increasing foraging efficiency and increasing reproductive success, such methods that are targeting spawners should be discouraged considering the long-term sustainability of the resource.

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